Development of an IoT-Based Vehicle Tracking System Using GPS NEO-6M and SIM800L Modules with SMS-Based Location Services

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ABSTRACT

Motor vehicle theft remains a significant security issue that causes considerable financial losses and inconvenience for vehicle owners. To address this problem, this study proposes the design and implementation of a low-cost Internet of Things (IoT)-based vehicle tracking system utilizing an Arduino Uno microcontroller, a GPS NEO-6M receiver, and a SIM800L GSM communication module. Unlike Internet-dependent tracking systems, the proposed system transmits real-time vehicle location information via Short Message Service (SMS), enabling reliable operation in areas with limited Internet connectivity. An experimental research methodology was employed, including system design, hardware implementation, software development, and field testing. The prototype was evaluated at thirteen different locations in Mojokerto and Sidoarjo, Indonesia, representing various environmental conditions such as open areas, commercial districts, shopping malls, residential zones, forests, and mountainous regions. The experimental results demonstrate that the developed system successfully acquired GPS coordinates and transmitted location information through SMS, allowing users to directly access the vehicle position using Google Maps. The results further indicate that positioning accuracy is influenced by environmental conditions, with higher accuracy achieved in open areas than in locations affected by satellite signal obstruction and multipath propagation. In addition, the communication subsystem exhibited reliable SMS transmission, while the prototype maintained low power consumption suitable for portable applications. Overall, the proposed system provides an economical, practical, and reliable solution for real-time vehicle tracking, particularly in regions where Internet connectivity is unavailable or unstable.

1 Introduction

The rapid advancement of the Internet of Things (IoT) has significantly transformed various aspects of modern life by enabling seamless communication among physical devices through the Internet. IoT technology integrates sensors, embedded systems, wireless communication networks, and cloud-based services to facilitate real-time data acquisition, monitoring, and intelligent decision-making [1]. One of the most promising applications of IoT technology is intelligent transportation systems, where real-time monitoring and tracking of vehicles have become increasingly important for improving transportation efficiency, enhancing security, and supporting logistics management [2]. As the number of motor vehicles continues to increase worldwide, ensuring vehicle safety has become a major concern for individual users, commercial transportation companies, rental agencies, and logistics service providers [3].

Motor vehicle theft remains one of the most common criminal activities in many developing countries, including Indonesia. According to reports from law enforcement agencies, thousands of motorcycles and automobiles are reported stolen every year, causing substantial financial losses and emotional distress to vehicle owners [4]. Conventional anti-theft systems, such as mechanical locks and alarm systems, primarily function as preventive security measures but do not provide real-time information regarding the vehicle's location after theft has occurred [5]. Consequently, there is an increasing demand for affordable, reliable, and easy-to-implement vehicle tracking systems capable of providing accurate location information in real time [6].

Recent developments in Global Positioning System (GPS) technology have enabled accurate positioning services for a wide range of applications, including navigation, environmental monitoring, disaster management, autonomous vehicles, and intelligent transportation systems [7]. GPS operates by receiving signals transmitted from multiple satellites orbiting the Earth and calculating the receiver's geographical coordinates through trilateration techniques. Modern GPS receivers are capable of achieving location accuracy within several meters under favorable environmental conditions. However, GPS performance can degrade significantly in dense urban environments, indoor areas, or regions surrounded by tall buildings due to signal blockage, multipath propagation, atmospheric disturbances, and satellite geometry [8].

To transmit positioning information to users, various wireless communication technologies have been employed, including Wi-Fi, Bluetooth, LoRaWAN, Sigfox, NB-IoT, LTE-M, and cellular communication networks. Among these technologies, the Global System for Mobile Communications (GSM) remains one of the most widely available communication infrastructures, particularly in developing

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countries where Internet connectivity may not always be reliable. By utilizing Short Message Service (SMS), GPS coordinates can be transmitted without requiring continuous Internet access, making SMS-based tracking systems highly practical for rural areas and locations with limited data network coverage. Furthermore, SMS communication offers relatively low implementation costs while maintaining compatibility with almost all mobile devices [9].

Several previous studies have proposed IoT-based vehicle tracking systems utilizing GPS and GSM modules. Most existing systems employ smartphone applications or cloud-based platforms to display vehicle locations through Internet services [10]. Although these approaches provide interactive visualization and advanced monitoring capabilities, they require stable Internet connectivity and cloud infrastructure, increasing both system complexity and operational costs. In contrast, SMS-based vehicle tracking systems offer a simpler architecture, lower deployment cost, and higher compatibility with areas where Internet access is limited. Nevertheless, many reported systems suffer from several limitations, including insufficient evaluation of positioning accuracy, limited analysis of communication reliability, high power consumption, and inadequate discussion regarding system performance under different environmental conditions [11].

The GPS NEO-6M module has become one of the most popular positioning modules for embedded applications due to its compact size, relatively low power consumption, high sensitivity, and compatibility with Arduino-based development platforms. Combined with the SIM800L GSM module, this hardware configuration enables an economical vehicle tracking system capable of transmitting geographical coordinates through SMS in real time. The Arduino Uno microcontroller serves as the central processing unit responsible for acquiring GPS data, formatting coordinate information, processing user commands, and managing communication between hardware modules. The integration of these components creates a compact embedded system suitable for low-cost vehicle monitoring applications [12].

Although numerous GPS tracking systems have been introduced in previous literature, relatively few studies comprehensively investigate the practical performance of SMS-based vehicle tracking devices under diverse environmental conditions. In particular, limited attention has been given to evaluating positioning accuracy across different urban and suburban locations, investigating the influence of signal obstruction and multipath effects, analyzing GSM communication reliability, and assessing battery consumption during continuous operation [13]. Furthermore, comparative analyses between open-area environments and densely populated commercial areas are rarely discussed in detail. These research gaps motivate the need for a more comprehensive experimental investigation using low-cost IoT hardware. [14]

In this study, an IoT-based vehicle tracking system utilizing the GPS NEO-6M module, SIM800L GSM module, and Arduino Uno microcontroller is designed and implemented to provide real-time vehicle location information through SMS communication. Unlike Internet-dependent tracking systems, the proposed system is capable of operating solely through the existing GSM network, making it suitable for deployment in regions with limited Internet accessibility. Experimental evaluations were conducted at thirteen different testing locations across Mojokerto and Sidoarjo, Indonesia, representing various environmental conditions, including historical sites, commercial areas, shopping malls, forests, residential districts, educational facilities, and mountainous regions. The system performance was evaluated in terms of positioning accuracy, communication reliability, operational stability, and power consumption.

The main contributions of this research can be summarized as follows:

1. A low-cost IoT-based vehicle tracking system integrating the GPS NEO-6M module, SIM800L GSM module, and Arduino Uno for real-time SMS-based location monitoring is proposed.
2. Comprehensive experimental evaluations were conducted at thirteen representative locations with diverse environmental characteristics to investigate the influence of surrounding conditions on GPS positioning performance.
3. System performance is analyzed in terms of GPS positioning accuracy, GSM communication reliability, operational stability, and battery power consumption under practical operating conditions.
4. The proposed system demonstrates that SMS-based vehicle tracking remains an effective, economical, and practical alternative for real-time vehicle monitoring in areas with limited Internet connectivity.

The remainder of this paper is organized as follows. Section II reviews related studies on IoT-based vehicle tracking systems and GPS technologies. Section III presents the proposed system architecture and hardware design. Section IV describes the experimental methodology. Section V discusses the experimental results and performance evaluation. Finally, Section VI concludes the paper and outlines future research directions.

2 Literature Study

The development of vehicle tracking systems has attracted significant attention over the last decade due to the increasing demand for intelligent transportation systems, anti-theft protection, fleet management, and location-based monitoring. Various studies have proposed different approaches by integrating Global Positioning System (GPS), Global System for Mobile Communications (GSM), microcontrollers, and Internet of Things (IoT) technologies. Although numerous systems have demonstrated promising performance, several limitations remain regarding communication reliability, implementation cost, power efficiency, and comprehensive experimental evaluation [15].

One of the earliest studies closely related to this work was conducted by Pangestu et al., who developed a motorcycle security and tracking system based on the GPS NEO-6M receiver, GSM SIM900 module, and an ATmega644PA microcontroller. Their system was capable of sending the geographical position of a motorcycle to the owner through SMS while also providing a remote security mechanism. The study demonstrated that integrating GPS and GSM technologies could effectively improve vehicle security with relatively simple hardware architecture. However, the

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proposed system mainly emphasized hardware implementation and basic functionality, while detailed evaluations regarding positioning accuracy, communication reliability, and environmental influences were not extensively discussed [16].

Another important contribution was presented by Nurhartono, who designed a vehicle security system capable of detecting stolen vehicles and displaying their location using Google Maps on a smartphone. The system combined an Arduino Uno, GPS receiver, GSM modem, and Google Maps integration to simplify vehicle monitoring. Experimental results showed that GPS coordinates transmitted through SMS could be successfully visualized on smartphones, allowing users to identify the vehicle's location. Nevertheless, the study primarily focused on demonstrating system functionality without providing comprehensive performance analyses under various environmental conditions, such as urban areas, commercial centers, and locations with limited satellite visibility [17].

Subsequent research extended GPS-based vehicle tracking by incorporating additional security features. For example, GPS trackers were integrated with engine immobilizers, RFID authentication, fingerprint recognition, and remote engine control to improve anti-theft protection. These approaches enhanced vehicle security by allowing owners not only to determine the vehicle position but also to disable engine operation remotely when unauthorized access was detected [18]. Although these systems improved overall security, they generally required additional hardware components, resulting in increased implementation costs, higher power consumption, and more complex installation procedures [19].

Several IoT-based vehicle monitoring systems have also been introduced using Internet communication instead of conventional SMS services. These systems typically transmit GPS coordinates to cloud servers through Wi-Fi, GPRS, or cellular Internet, enabling real-time monitoring via mobile applications or web dashboards. Cloud-based monitoring provides attractive graphical interfaces and continuous location updates. However, such systems depend heavily on stable Internet connectivity and cloud infrastructure. Consequently, their deployment becomes less practical in rural areas or regions where Internet access is unstable or unavailable. SMS-based communication remains a practical alternative because it utilizes the existing GSM network and can operate even in areas without mobile Internet services [20].

Although previous studies have successfully demonstrated the feasibility of GPS-GSM vehicle tracking systems, several research gaps remain. First, many existing studies evaluate system functionality only through limited field testing without conducting comprehensive experiments in multiple environmental conditions. Second, the influence of surrounding infrastructure, such as high-rise buildings, dense vegetation, commercial complexes, and mountainous terrain, on GPS positioning accuracy has not been thoroughly investigated. Third, only a few studies analyze operational parameters such as GSM communication reliability, SMS delivery performance, battery endurance, and system stability during prolonged operation. These aspects are essential for determining whether a tracking device is suitable for practical deployment in real-world transportation environments [21].

Compared with previous studies, the proposed research employs a similar low-cost hardware architecture consisting of an Arduino Uno, GPS NEO-6M receiver, and SIM800L GSM module but extends the experimental evaluation considerably [22]. Rather than focusing solely on successful coordinate transmission, this study evaluates system performance across thirteen testing locations representing diverse environmental characteristics, including historical sites, commercial districts, shopping malls, forests, educational facilities, residential areas, and mountainous regions [23]. Furthermore, the proposed work analyzes GPS positioning performance, communication reliability, operational stability, and power consumption, providing a more comprehensive assessment of the tracking system under realistic operating conditions [24].

Therefore, this study not only validates the feasibility of implementing a low-cost SMS-based IoT vehicle tracking system but also contributes a broader experimental analysis that addresses several limitations identified in previous research. The findings are expected to provide useful insights for researchers and practitioners interested in developing reliable and economical vehicle tracking systems suitable for deployment in regions with limited Internet infrastructure.

3 Methodology

3.1 Research Method

This study employed an experimental research methodology to design, implement, and evaluate an Internet of Things (IoT)-based vehicle tracking system utilizing the GPS NEO-6M receiver, SIM800L GSM communication module, and Arduino Uno microcontroller. The experimental approach was selected because it enables direct observation and performance evaluation of the developed prototype under actual operating conditions.

The research methodology consisted of four main stages: system design, hardware and software implementation, experimental testing, and performance evaluation. Initially, the vehicle tracking system was designed by integrating the GPS receiver, GSM communication module, Arduino Uno, and a power supply into a single embedded platform. Subsequently, the software was developed using the Arduino Integrated Development Environment (Arduino IDE) to manage GPS data acquisition, SMS communication, and command processing.

Following the implementation stage, the prototype was experimentally evaluated by conducting a series of field tests under various environmental conditions. The testing process aimed to verify the functionality of each hardware component, evaluate the reliability of GPS positioning, assess GSM communication performance, and measure the operational stability of the entire system. The experimental results were then analyzed to determine the effectiveness of the proposed vehicle tracking system in providing real-time location information through SMS communication.

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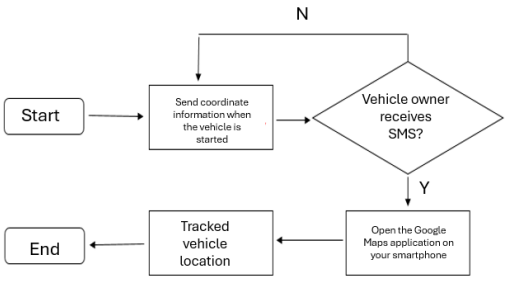

Figure 1. Research Method Flowchart

3.2 *Proposed System Architecture*

The overall architecture of the proposed vehicle tracking system is illustrated in Figure 2. The system consists of four primary components: an Arduino Uno microcontroller, a GPS NEO-6M positioning module, a SIM800L GSM communication module, and a smartphone used by the vehicle owner. Google Maps serves as the visualization platform for displaying the received vehicle coordinates.

The GPS receiver continuously obtains geographical coordinates from GPS satellites. The acquired latitude and longitude information is transmitted to the Arduino Uno through serial communication. The Arduino processes the received coordinate data and continuously monitors incoming SMS commands from the authorized user through the SIM800L GSM module.

When the user sends a predefined SMS command, the Arduino retrieves the latest GPS coordinates, generates a Google Maps hyperlink, and transmits the location information back to the user via SMS. By opening the received hyperlink on a smartphone, the user can immediately identify the current location of the tracked vehicle. This architecture eliminates the dependency on Internet connectivity while maintaining reliable real-time vehicle tracking through the existing GSM cellular network.

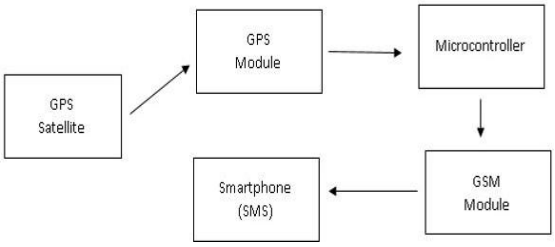

Figure 2. Overall System Architecture

3.3 *Circuit Flowchart*

The hardware implementation consists of three primary embedded devices integrated into a compact vehicle tracking unit, namely the Arduino Uno microcontroller, the GPS NEO-6M receiver, and the SIM800L GSM communication module.

The Arduino Uno functions as the main controller responsible for coordinating communication between all hardware modules. It continuously receives GPS coordinate data, processes user requests, and controls SMS communication through the GSM module.

The GPS NEO-6M receiver serves as the positioning subsystem by calculating the geographical location of the vehicle based on signals received from GPS satellites. Under open-sky conditions, the module provides accurate latitude and longitude coordinates, which are subsequently processed by the Arduino.

Meanwhile, the SIM800L module functions as the wireless communication subsystem. It receives SMS commands from authorized users and transmits vehicle location information through the GSM cellular network. The communication between these modules is established using UART serial communication.

The complete hardware prototype of the proposed vehicle tracking system is presented in Figure 3, while the electrical connections among the Arduino Uno, GPS module, and GSM module are summarized in Table I.

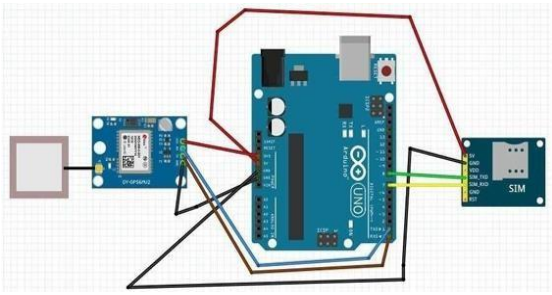

Figure 3. Hardware Prototype of the Proposed Vehicle Tracking System

Table I. Wiring Configuration of Arduino Uno, GPS NEO-6M, and SIM800L

Ublox Neo-6m	Arduino Uno	Sim800I V2	Arduino Uno
VCC	3.3 V	VCC	5V
Gnd	Gnd	Gnd	Gnd
RX	1	RX	7
TX	0	TX	8

3.4 *Software Design*

The embedded software was developed using the Arduino Integrated Development Environment (Arduino IDE). The program performs four major tasks: initialization of the GPS and GSM modules, continuous acquisition of GPS coordinates, monitoring of incoming SMS commands, and transmission of vehicle location information.

After initialization, the Arduino continuously receives NMEA data generated by the GPS receiver. The latitude and longitude information are extracted and temporarily stored in memory. Simultaneously, the SIM800L module continuously monitors incoming SMS messages.

When an SMS containing the predefined command "CEK" is received, the Arduino validates the command and retrieves the latest GPS coordinates. The coordinates are then formatted into a Google Maps hyperlink before being transmitted back to the user through the GSM network.

This software architecture enables continuous vehicle monitoring while minimizing communication overhead and reducing unnecessary SMS transmissions.

3.5 *System Implementation*

The implementation of the proposed system integrates both hardware and software components into a single operational prototype. During operation, the GPS receiver continuously searches for available satellites and updates the geographical coordinates of the vehicle.

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After obtaining a valid GPS fix, the Arduino stores the latest coordinate information and waits for an SMS request from the authorized user. Upon receiving the predefined "CEK" command, the Arduino immediately retrieves the most recent coordinate data and sends a reply message containing a Google Maps hyperlink.

If the GSM network is temporarily unavailable, the user may resend the command once network coverage has been restored. This simple communication mechanism allows the system to operate reliably without requiring Internet access or cloud-based services.

3.6 Experimental Setup

To evaluate the performance of the proposed vehicle tracking system, experimental testing was conducted at thirteen different locations distributed across Mojokerto and Sidoarjo, Indonesia. These locations were intentionally selected to represent various environmental characteristics, including historical sites, commercial areas, shopping malls, residential districts, educational facilities, forests, and mountainous regions.

The experiments were carried out from September 2025 to February 2026. During each experiment, the vehicle tracking device was positioned at a predefined location, and the user transmitted the "CEK" command via SMS to request the current vehicle coordinates.

The coordinates received through SMS were subsequently opened in Google Maps and compared with the actual reference location to evaluate positioning accuracy. In addition to coordinate accuracy, the experiments also observed SMS communication reliability, response time, operational stability, and battery consumption under different environmental conditions.

3.7 Performance Evaluation

The performance of the proposed vehicle tracking system was evaluated using several technical parameters to assess its practicality for real-world applications.

The first evaluation parameter was GPS positioning accuracy, which was determined by comparing the coordinates transmitted by the proposed system with the corresponding reference coordinates obtained from Google Maps. The positional deviation was analyzed to determine the accuracy of the GPS module under different environmental conditions.

The second parameter was SMS communication reliability, which evaluated the ability of the SIM800L module to successfully receive user commands and transmit vehicle coordinates through the GSM network.

The third parameter was system operational stability, which assessed whether the integrated hardware components could operate continuously without communication failures or unexpected interruptions during prolonged testing.

Finally, power consumption was evaluated by monitoring battery utilization during continuous operation to estimate the practical operating duration of the proposed tracking device. The combination of these evaluation parameters provides a comprehensive assessment of the effectiveness, reliability, and practicality of the developed IoT-based vehicle tracking system.

4 Result and Discussion

4.1 Prototype Implementation

After completing the hardware assembly and software development, the proposed IoT-based vehicle tracking system was successfully implemented as a functional prototype. The prototype integrates an Arduino Uno microcontroller, a GPS NEO-6M receiver, a SIM800L GSM communication module, and a rechargeable power supply into a compact embedded device.

The GPS receiver continuously acquires geographical coordinates from GPS satellites, while the Arduino Uno processes the received information and manages communication with the GSM module. Upon receiving the predefined SMS command "CEK", the SIM800L module transmits the latest vehicle coordinates to the user's smartphone in the form of a Google Maps hyperlink.

The completed hardware prototype is shown in Figure 4, while Figure 5 illustrates an example of the SMS response received by the user.

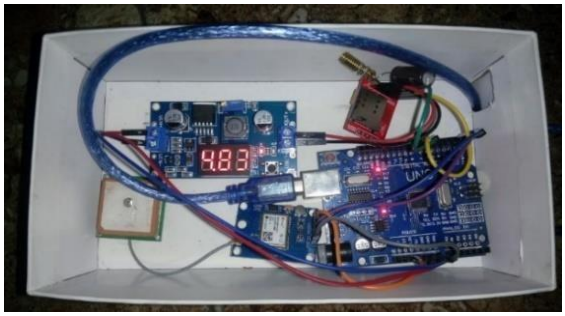

Figure 4. Prototype of the Proposed Vehicle Tracking System

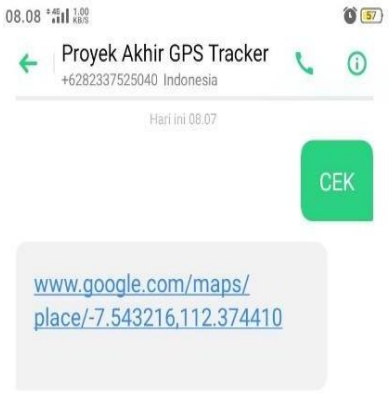

Figure 5. SMS Response Containing Google Maps Link

The implementation results demonstrate that all hardware modules communicate properly through UART serial communication. During the experiments, the system successfully obtained GPS coordinates and transmitted location information through the GSM cellular network without requiring Internet connectivity.

4.2 GPS Positioning Performance

The positioning performance of the proposed tracking system was evaluated through experimental testing conducted at thirteen different locations distributed across Mojokerto and Sidoarjo, Indonesia. The selected locations represented various environmental conditions, including historical sites, commercial buildings, shopping malls, residential areas, educational facilities, forests, and mountainous regions.

The primary objective of this experiment was to evaluate the ability of the GPS NEO-6M module to determine accurate geographical coordinates under different satellite visibility conditions. For each testing location, the user transmitted the predefined SMS command to request the current coordinates. The coordinates returned by the tracking system were then compared with the corresponding reference location displayed in Google Maps.

The experimental results indicate that the proposed system successfully acquired valid geographical coordinates at all testing locations. Under open-area conditions, such as Candi Brahu and Mojokerto City Square, the GPS receiver demonstrated higher positioning accuracy due to unobstructed satellite visibility.

Conversely, locations surrounded by tall buildings, dense vegetation, or mountainous terrain exhibited relatively lower positioning accuracy because of satellite signal obstruction and multipath propagation effects. These environmental factors increase positioning uncertainty and slightly affect coordinate precision. Overall, the experiments confirmed that the GPS NEO-6M receiver provides sufficient positioning accuracy for practical vehicle tracking applications.

4.3 SMS Communication Performance

The communication performance of the proposed system was evaluated by observing the ability of the SIM800L GSM module to receive SMS commands and transmit GPS coordinates to the authorized user. During the experiments, the communication subsystem successfully received incoming SMS requests and generated response messages containing Google Maps hyperlinks. The received hyperlinks could be directly opened on Android smartphones, allowing users to identify the current vehicle location.

The communication reliability was strongly influenced by GSM network availability. Areas with stable cellular coverage exhibited fast SMS delivery, whereas remote or mountainous regions occasionally experienced transmission delays due to weaker GSM signals. Nevertheless, no communication failures were observed during the testing period, demonstrating that SMS remains a reliable communication medium for vehicle tracking applications in areas without Internet connectivity.

4.4 Power Consumption Analysis

Power consumption is an important consideration for embedded vehicle tracking systems operating on rechargeable batteries. During the experimental evaluation, the battery level decreased from approximately 100% to 30% after one day of continuous operation.

The observed power consumption indicates that the developed prototype is capable of operating for more than two days under normal usage conditions, depending on the frequency of SMS communication and GPS positioning updates.

Although the obtained battery lifetime is considered adequate for practical implementation, additional power optimization techniques, such as sleep mode operation, duty cycling, or larger battery capacity, could further extend the operational duration.

4.5 Discussion

The experimental results demonstrate that the proposed IoT-based vehicle tracking system successfully integrates GPS positioning and GSM communication into a reliable low-cost embedded platform. One of the main advantages of the proposed system is its independence from Internet connectivity. Unlike cloud-based vehicle tracking systems, the developed prototype only requires GSM network availability, making it suitable for rural and remote areas where mobile Internet services may be unavailable.

The positioning accuracy primarily depends on satellite visibility. Open environments consistently produced better positioning performance than locations surrounded by tall buildings or dense vegetation. This observation is consistent with the well-known influence of multipath propagation and satellite obstruction on GPS positioning accuracy.

Furthermore, the SIM800L communication module demonstrated reliable SMS transmission throughout the experimental evaluation. Although transmission delays were occasionally observed in areas with weak GSM coverage, all SMS messages were successfully delivered to the intended recipient.

The battery performance also indicates that the developed system is suitable for continuous vehicle monitoring applications. Nevertheless, future work should investigate low-power embedded architectures and intelligent power management techniques to further improve operational efficiency. Overall, the proposed vehicle tracking system provides an economical, reliable, and practical solution for real-time vehicle monitoring, particularly in environments where Internet connectivity is limited.

5 Conclusion

This study successfully designed, implemented, and evaluated an IoT-based vehicle tracking system using an Arduino Uno, a GPS NEO-6M receiver, and a SIM800L GSM module to provide real-time vehicle location monitoring through SMS communication. Experimental evaluations conducted at thirteen different locations in Mojokerto and Sidoarjo demonstrated that the proposed system reliably acquired GPS coordinates and successfully transmitted location information via SMS, which could be directly visualized using Google Maps. The experimental results also indicated that positioning accuracy was influenced by environmental conditions, with better performance observed in open areas than in locations affected by signal obstruction and multipath propagation. In addition, the system exhibited satisfactory communication reliability and low power consumption, making it suitable for practical vehicle security applications, particularly in areas with limited Internet connectivity. Future work will focus on improving positioning accuracy, optimizing power management, and integrating cloud-based monitoring and mobile applications to enhance the overall performance and functionality of the proposed system.

Author Contribution

Conceptualization, Author 1 and Author 2; methodology, Author 5; software, Author 1; validation, Author 6, Author 2, Author 3, and Author 4; formal analysis, Author 1; investigation, Author 1 and Author 2; resources, Author 1 and Author 2; data curation, Author 5; writing—original draft preparation, Author 1; writing—review and editing, Author 2, Author 3, and Author 4; visualization, Author 3; supervision, Author 2; project administration, Author 1 and Author 2.

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